

**SOLE**

**APPLICATION  
FOR  
UNITED STATES LETTERS PATENT**

**TO THE ASSISTANT COMMISSIONER FOR PATENTS:**

BE IT KNOWN, that I, **Howard Sosin** of Fairfield, CT  
have invented certain new and useful improvements in an IMPACT AND ROLL  
MEASUREMENT DEVICE of which the following is a specification:

## IMPACT AND ROLL MEASUREMENT DEVICE

### Priority Information

The present application claims priority to provisional application U.S. Serial No. 60/250,894, filed November 29, 2000, the entire contents of which are incorporated herein by reference.

### Background of the Invention

Indicia of a successful golf shot include the flight, roll, and ultimate resting spot of the ball, the sensation of hit in the hands, and the size, shape, and location of any divot produced. The divot (alone or in conjunction with the golfer's stance, ball position, etc.) can reveal a great deal about a golf shot, e.g., whether the shot was fat, thin, pushed, pulled, etc. More and more golf facilities are foregoing grass for artificial turf, and in the process are depriving golfers of the feedback from their divots.

A few systems have been proposed to provide feedback to a golfer during practice on artificial turf. For example, U.S. Patent No. 3,992,013 to Golden proposes a method of measuring where a club has contacted the ground by spreading a thin film of chalk dust over a resilient mat on which the ball is placed. The golfer can examine the pattern of chalk dust dispersed by the club to determine the path of the club head. U.S. Patent No. 4,223,891 to van Gaasbeek *et al.* discloses a mat having eight switches that provide some feedback to the golfer of which switches were hit during the swing and in what order.

A system is still lacking that can provide a golfer practicing on artificial turf with detailed information about his divot.

### Summary of the Invention

In one aspect, the invention provides an artificial turf that includes fibers protruding from or embedded within a substrate. The fibers include a chromogen that responds to a change in environmental conditions by changing from a first color to a

second color, these colors being visually distinguishable. The change in environmental conditions may involve a change in temperature, an elastic elongation, a change in chemical conditions, or a combination thereof. The change in environmental conditions is associated with an impact between the fibers and an object, *e.g.*, a golf club head. The 5 fibers may comprise or consist of the chromogen, or they may comprise a coating of the chromogen on a core of a different material. The turf may further comprise indicia, for example for locating a golf ball on the turf before swinging or for locating the boundaries of a sports field.

In another aspect, the invention provides a color changing material that includes a 10 substrate and a film that is disposed on a surface of the substrate. The film includes a chromogen and responds to a change in environmental conditions by changing from a first color to a second color, these colors being visually distinguishable. The color changing material may be designed such that the film changes from the first to the second color along the path of a ball rolling along its surface.

15 **Brief Description of the Drawing**

The invention is described with reference to the several figures of the drawing, in which:

Figure 1 is a side view of a golf mat according to the invention;  
Figures 2a-2d illustrate the behavior of the fibers when a ball placed on the mat 20 is struck by a golf club head during a golf swing; and  
Figures 3 and 4 are top views of a golf mat according to the invention.

**Detailed Description**

The present application mentions various patents, scientific articles, and other publications. The contents of each such item are hereby incorporated by reference.

25 The present invention exploits the ability of certain substances (so-called “chromogens”) to change color when subjected to a change in environmental conditions.

The change in environmental conditions may involve a change in physical conditions, e.g., temperature or stress; a change in chemical conditions, e.g., exposure to a chemical or solvent; or a combination thereof. The change from a first color to a second color may be from colorless to colored, from colored to colorless, or from colored to colored (e.g., 5 red to blue, blue to red, etc.). Preferably the change in color occurs in the visible region and is sufficient for it to be distinguishable by the naked eye. Although not preferred, the present invention also encompasses the use of chromogens that exhibit a color change in the ultraviolet or infrared regions of the spectrum. The change in color may be reversible or irreversible. In preferred embodiments, the change in color is reversible.

10 A variety of reversible and irreversible chromogens are known in the art including a range of polymeric molecules, organic molecules, metal cluster compounds, organometallic complexes, etc. (for a review, see "Chromogenic Materials" vol.6, pp. 312-343 in *Kirk Othmer Encyclopedia of Chemical Technology* Ed. by Howe-Grant, 4th Edn., John Wiley & Sons, New York, NY, 1993). Some exemplary chromogens that may 15 be used with the present invention are described in greater detail below. It is to be understood that any suitable chromogenic substance may be used with the present invention, and that the present invention is in no way limited to the exemplary chromogens described herein.

With reference to **Figure 1**, a golf mat 18 according to the invention comprises a 20 substrate 10 having a plurality of fibers 12 protruding therefrom, preferably in substantially the same configuration as typical artificial turf (see, for example, U.S. Patent Nos. 6,139,443 to Reynolds and 4,932,663 to Makar). At least a portion of the fibers 12 comprise one of the chromogens mentioned above and further described below. Depending on the nature of the chromogen and the fibers, it may be desirable to coat the 25 chromogen on the surface of the fibers; to incorporate the chromogen within the core of the fibers, e.g., as a mixture, blend, or composite; or to associate the chromogen with the synthetic polymers that make up the fibers, e.g., as a co-polymer, a covalently bonded

group, or a non-covalently bonded group, *e.g.*, hydrogen bonded, ionically bonded, etc. When using a coating approach, it is to be understood that the chromogen may be applied onto the surface of the fibers by any known method, *e.g.*, dip coating, spray coating, brush coating, roll coating, spin casting, or some combination thereof. The present

5 invention encompasses methods that involve spray coating pre-fabricated golf mats with a suitable chromogen. The present invention further encompasses the use of co-extrusion methods that produce fibers having a “core-sheath” structure, wherein the core or sheath includes a chromogen. A coating approach may enhance the visibility of the color change of the chromogen in some circumstances, *e.g.*, when using opaque fibers. When

10 using a polymeric chromogen having suitable mechanical properties it may even be desirable to manufacture fibers from the chromogen itself. In certain embodiments, it may prove advantageous to encapsulate the chromogen, *e.g.*, when the chromogen is a liquid or dissolved in a liquid medium

When a chromogenic substance of the present invention is coated onto or incorporated into fibers, the amount of the chromogenic substance necessary for obtaining a desired color change can be varied within a broad range and is essentially decided based on factors such as the nature of the chromogen, the nature of the fibers, and the nature of the fiber manufacturing process. In order to improve various properties of the resulting fibers, it is possible to add thereto additives as are usually employed in the art. For example, one may include antioxidants, ultraviolet absorbers, inorganic fillers, plasticizers, lubricants, and the like.

The behavior of the fibers 12 when a ball placed on the mat is struck is shown in **Figures 2a-2d**. As the golf club head 14 approaches the ball 16, it may contact fibers 12 behind the ball as shown in **Figure 2a** (this will be particularly true for “fat” shots).  
25 **Figure 2b** shows the golf club head 14 striking the ball 16, and also beginning to stretch the fibers 12 behind the ball 16 that were contacted as shown in **Figure 2a**. As the golfer “follows through”, more fibers 12 are contacted and stretched, as shown in **Figure 2c**. If

the swing is one that would take a divot, more fibers 12 ahead of the ball 16 will be contacted and stretched by the golf club head 14, as shown in **Figure 2d**. The fibers 12 are significantly stretched because of the rapidity of the impact; this effect can be enhanced by making the surface of the fibers 12 somewhat rough to increase its stickiness. In addition, the stretching and friction between the golf club head 14 and the surface of the fibers 12 generates a significant amount of heat at the point of impact. This heating effect is partially responsible for the rapid decomposition of golf mats made from low-melting point fibers, e.g., polypropylene fibers that have a melting point of about 160 °C.

10       **Figure 3** shows an overhead view of a golf mat 18 according to the invention immediately after a swing. Region 20 shows where the golf club head has passed close enough to the ground to impact the fibers, while indicial mark 22 shows the location of the ball before the swing and regions 24 show where the golfer's feet are placed. As shown, the swing apparently was somewhat "pulled," as can be seen by the shape of 15 region 20. Few fibers behind the indicial mark 22 have changed color, indicating that the shot was not "fat".

As alternatives to indicial mark 22 the mat could be marked with lines 26 and 28 indicating foot placement and ball position, respectively, as shown in **Figure 4**. Alternatively, the golfer could create his own indicia by dragging a club or other object 20 along the mat in order to induce a color change showing where the shot should be placed.

Since its configuration is so similar to that of artificial turf, no special clubs or equipment are needed to use the golf mat of the invention. However, it can readily be combined with other devices designed to simulate the tactile response of a natural surface, such as those disclosed in U.S. Patent Nos. 4,932,663 to Makar, 4,955,611 to 25 Moller, 5,356,147 to MacDonald, and 5,888,147 to Luedtke, or with other measurement or training devices.

In certain embodiments the fibers include a “stress chromic” polymer that changes color when subjected to external stress, *i.e.*, when elongated. The stretching of the fibers and hence of the stress chromic polymer produces a visible color change, so that the golfer can observe a close approximation to his divot. The fiber material is

5 preferably selected to have a suitable elasticity and a relatively slow rebound time (*i.e.*, gel-like behavior), so that the golfer has an opportunity to view the color change after completing the follow-through of his swing. In preferred embodiments of the invention, the color change remains visible for 1-30 seconds, preferably for 2-15 seconds, and more preferably for 3-10 seconds. If the fibers have a shorter rebound period, the invention

10 may still be used by allowing an observer to watch the color change during the golf swing. Alternatively, an automated observing system could photograph the area before the color change fades, and could display an image of the divot to the golfer.

The optical properties of polymers are a function of their conformation and electronic structure. In contrast to many inorganic materials, polymers having

15 polycrystalline microstructures are generally translucent or opaque, while highly amorphous polymers are usually transparent. Light transmission through polymers having crystalline regions is degraded by scattering from the crystalline domains. In addition, highly conjugated polymers may have electronic structures that permit absorption at visible wavelengths. The absorption wavelengths depend on the

20 composition of the polymer backbone and side groups. The electronic interactions among the backbone and side groups can be modified by externally applied mechanical forces. For example, polydiacetylenes absorb at higher frequencies when subjected to a tensile load. This effect is reversible, and the absorption frequency decreases when the stress is released (see Nallicheri and Rubner, *Macromolecules* 24: 517, 1991). The

25 change in absorption frequency alters the reflected wavelengths commensurately, changing the color of the material, in this particular case between red and blue.

In a specific example, polyurethane segments of block co-polymer are cross-linked with polydiacetylene. The polyurethane segments are rigid and are linked by a softer polymer segment, poly(tetramethylene oxide). A pendant group such as a phenyl group may also be included in the urethane segment. The microstructure of the polymer depends on the composition. Composition-dependent elements of the microstructure include the size and crystallinity of the hard domains, the degree of phase separation, and the interconnectedness of the two phases. For appropriate microstructures, the polymer is an elastomer that experiences a color change when stretched. The degree of stress necessary to cause the change and the intensity of the color both depend on the composition of the stress chromic polymer. In preferred embodiments of the invention, the color change occurs after 1-100 % elongation, preferably after 1-50 % elongation, and more preferably after 1-25 % elongation. In addition, the wavelength of the new color is composition-dependent. When subjected to tensile stress, the polydiacetylene polymer also experiences an anisotropic color change wherein horizontally and vertically polarized light are not absorbed in the same manner (Nallicheri and Rubner, 1991, *supra*).

Additionally or alternatively, the fibers may include a “thermochromic” substance that changes color as a consequence of the local temperature change generated by the impact. In certain embodiments, the chromogen may be both stress chromic and thermochromic. Angkaew *et al.* describe homogeneous molecular composites made from diacetylene monomers containing biphenol mesogenic groups and alkyl spacers that exhibit both stress and thermal chromic transitions (see Angkaew *et al.*, *Chem. Mater.* 6:1444, 1994). For example, when stress was applied to a polymer film of 8-8DABP the color of the film changed from blue to reddish purple and returned to blue when the stress was released. When the film was heated, it was found to change gradually and continuously from blue to purple (at about 35 °C), from purple to orange (at about 50-55 °C), and from orange to yellowish gold (at about 110-120 °C). The chromic transition

occurred quickly and the reversibility was found to be permanent over many cycles of heating and cooling (at least up to 100 cycles). Polymers of 3-8DABP behaved in a similar manner but with a color change from pink to red and then red to orange with increased temperature. The present invention encompasses the use of coolers and/or heaters that maintain the golf mat at a suitable temperature prior to impact. The present invention further encompasses methods that involve heating golf club heads prior to taking a golf swing in order to increase the local temperature change at impact. The color change may occur gradually with heating or may occur at a specific temperature.

Preferred thermochromic substances exhibit a gradual or sharp color change within a range of temperatures between about 0 °C and 200 °C, more preferably between about 20 °C and 200 °C, even more preferably between about 25 °C and 200 °C, and most preferably between about 35 °C and 200 °C.

Many examples of thermochromic substances are to be found in 3d transition metal complexes and other 3d metal compounds (see *Inorganic Thermochromism* by Sone and Fukuda, Springer Verlag, Germany, 1987). For example, the copper metal complexes  $[(C_2H_5)_2NH_2]_2CuCl_4$  and  $[(CH_3)_2NH_2]_3CuCl_5$  both exhibit solid state thermochromic transitions. The  $[(C_2H_5)_2NH_2]_2CuCl_4$  complex undergoes a discontinuous and reversible green-to-yellow color transition at about 50 °C (see Bloomquist *et al.*, *J. Am. Chem. Soc.* 110:7391, 1988). In contrast, the  $[(CH_3)_2NH_2]_3CuCl_5$  complex undergoes a continuous and gradual color change (see Willett *et al.*, *Inorg. Chem.* 13:2510, 1974). Complexes with the general chemical formula  $M(N,N\text{-diethylenediamine})_2(X)_2$ , where M is  $Cu^{2+}$  or  $Ni^{2+}$  and X is an anion are also thermochromic in the solid-state. The nature of the color change depends in part on the ease with which the anion X becomes disordered. While easily disordered anions (*e.g.*,  $ClO_4^-$  and  $BF_4^-$ ) lead to a sharp transition, complexes that include anions that are not easily disordered generally exhibit a gradual transition (see Bloomquist and Willett, *Coord. Chem. Rev.* 47:125, 1982). Other metal complexes that may be used according to

the present invention include  $\text{Ag}_2\text{HgI}_4$  which changes from yellow to orange at 50 °C and  $\text{Cu}_2\text{HgI}_4$  which changes from red to brown at 70 °C.

A multitude of organic thermochromic substances are also known in the art including, but not limited to, diaryl phthalides, polyaryl carbinols, leuco auramines, lactum leuco compounds, indolines, spiropyrans and fluoranes (see Nassau in *The Physics and Chemistry of Color*, pp. 77-109, John Wiley & Sons, New York, NY, 1983; Bachteler, *Contemp. Phys.*, 29:3, 1988; *Organic Photochromic and Thermochromic Compounds* Ed. by Crano and Guglielmetti, Kluwer Academic Publishers, The Netherlands, 1998; see also U.S. Patent Nos. 4,028,118 to Nakasuji and 5,480,482 to Novinson). Encapsulated and non-encapsulated thermochromic compositions including pigments and dyes for inks and paints have been described, see for example, U.S. Patent Nos. 6,290,977 to Friars *et al.*; 5,997,849 to Small; 5,194,183 to Munch *et al.*; 4,743,398 to Brown *et al.*; and 4,105,583 to Glover *et al.* Typically, thermochromism of these compounds involves some form of rearrangement of the molecular structure of a dye, as a result of a change in temperature. Typically, a colorless dye precursor and a color developer are both dissolved in an organic solvent. The solution is then encapsulated, and is solid at lower temperatures. Upon heating, the system becomes colored or loses color at the melting point of the mixture. The reverse change occurs at this temperature if the mixture is then cooled.

Chiral nematic liquid crystals that include molecules arranged helically, may also be used as thermochromic substances in the present invention. Thermochromism results from the selective reflection of light by the liquid crystals. The wavelength of the light reflected is governed by the refractive index of the liquid crystal and by the pitch of the helical arrangement of its molecules. Since the length of the pitch varies with temperature, the wavelength of the reflected light is also altered, and color changes result (for a review see, for example, "Thermotropic Liquid Crystals" by McDonnell in *Critical Reports on Applied Chemistry*, vol. 22, pp. 120-144, Ed. by Gray, John Wiley & Sons,

New York, NY, 1987). Since these thermochromic materials exist as liquid crystals it will be appreciated that they are preferably encapsulated prior to incorporation into or coating onto inventive fibers, *e.g.*, using conventionally known techniques such as, in-situ polymerization, interfacial polymerization, coacervation, in-liquid drying, spray drying 5 and other methods as described in, for example, U.S. Patent Nos. 6,228,804 to Nakashima; 5,503,781 and 5,350,634 to Sumii *et al.*; and 6,030,668 to Hall *et al.*

A variety of thermochromic organic polymers are also known, *e.g.*, poly(xylylviologen dibromide) which exhibits a sharp color change at about 100 °C as a consequence of dehydration (see Moore and Stupp, *Macromolecules* 19:1815, 1986); 10 urethane-substituted polydiacetylene which changes color due to thermally induced conformational transitions of the unsubstituted backbone (see Rubner *et al.*, *Macromolecules* 20:1296, 1987); and others (see, for example, Holdcroft, *Macromolecules* 29:6510, 1996 and Dufresne *et al.*, *Macromolecules* 33:8252, 2000). Certain poly(di-*n*-alkylsilanes) and germanes exhibit large temperature dependent 15 ultraviolet spectral changes. For example, the peak ultraviolet absorption of poly(di-*n*-hexylsilane) shifts from 374 nm to 317 nm at 41 °C (see Miller *et al.*, *J. Am. Chem. Soc.* 107:2172, 1985).

It is to be understood that the present invention encompasses the use commercially available thermochromic substances, *e.g.*, those available from Color 20 Change Corp. of Addison, IL; Clark R & D of Rolling Meadows, IL; Image Therm Engineering, Inc. of Sudbury, MA; Hallcrest, Inc. of Glenview, IL; Thermographic Measurements Inc. of Northbrook, IL; and Chromatic Technologies of Colorado Springs, CO. It is further to be understood that commercially available plastics that include a thermochromic substance, *e.g.*, those sold under the trademarked name COLORCOMP™ 25 by LNP Engineering Plastics of Exton, PA, may also be used in the present invention.

In other embodiments, the fibers may be coated with a “chemically chromic” substance that changes color as a consequence of a change in chemical environment (*e.g.*,

solvent or pH). In such an embodiment, one may, for example, envisage dipping the golf club head in a suitable solvent (*e.g.*, ethanol, DMSO, hexane, water, etc.), or solution (*e.g.*, a slightly acidic or basic aqueous solution) and then taking a practice swing on the inventive golf mat. Upon impact with the golf mat, the solvent or solution would be  
5 transferred onto the fiber surface thereby changing the local chemical environment of the chromogen. In certain embodiments, the solvent or solution may be volatile and thereby impart a secondary cooling effect on the fibers as it evaporates that could cause a thermochromic substance to change color.

As is well known in the art, substances that have a large molecular  
10 hyperpolarizability are highly sensitive to their chemical environment and therefore may change color when exposed to different solvents, *e.g.*, the dyes described in U.S. Patent Nos. 5,591,848 to Maslak (spiroconjugated charge-transfer dyes); 5,623,075 to Beckmann *et al.* (thiazolemethine dyes); 5,068,318 to Decher *et al.* (diameno-dinitroazo dyes); and 4,948,895 to Chen *et al.* (benzofuran dyes). A variety of dyes are also known  
15 that change color with pH, *e.g.*, Crystal Violet lactone that turns from colorless to a deep blue upon protonation, and standard pH indicator dyes that exhibit a different color above and below their pK<sub>a</sub> value, *e.g.*, thymol blue (changes from red to yellow above pK<sub>a</sub> 1.5 and from yellow to blue above pK<sub>a</sub> 8.9); methyl orange (changes from red to yellow above pK<sub>a</sub> 3.7); bromocresol green (changes from yellow to blue above pK<sub>a</sub> 4.7); methyl  
20 red (changes from yellow to red above pK<sub>a</sub> 5.1); bromothymol blue (changes from yellow to blue above pK<sub>a</sub> 7.0); phenol red (changes from yellow to red above pK<sub>a</sub> 8.9); and phenolphthalein (changes from colourless to pink above pK<sub>a</sub> 9.4).

Irrespective of the nature of the chromogen, the color change is preferably fully reversible, so that many swings can be made in succession on the same surface.  
25 However, a quasi-reversible color change, *e.g.*, when using a chromogen that shows hysteresis of chromism is also encompassed by the present invention. In addition, an irreversible color change is also within the scope of the invention. In such embodiments,

the golfer may either swing at the same location (in which case he will see the location of the second divot superimposed on the first), or he may move the ball from place to place on the surface in order to use areas that have not yet changed color. It is also within the scope of the invention to use a material that requires heat or chemical means to remove

5 the color change (*e.g.*, a chromogen may be used whose color change may be reversed by application of heat from a heat gun, by cooling, by washing with a particular solvent or solution, etc.).

A number of synthetic polymers have been used to prepare fibers for artificial turf products, including polyesters, polyamides (*e.g.*, nylon), aramides, polyimides, acrylics,

10 cellulosic polymers, polyolefins (*e.g.*, polyethylene and polypropylene), and vinyl polymers. The majority of these polymers exhibit high tensile strength, high tensile modulus and therefore relatively low elongation at break. It will be appreciated that although such polymers may be appropriate for use with thermochromic and chemically chromic substances, they may be less suitable for use with stress chromic substances. It  
15 is therefore to be understood that the present invention is not limited to using these “conventional” fiber compositions, and that the polymeric composition, cross section, elastic properties, mechanical properties, etc. of the fibers will depend on the nature of the chromogen and the desired application of the artificial turf. In particular when using stress chromic substances, it may prove advantageous to use fibers that include these  
20 “conventional” polymers blended with elastomers and/or gel-like polymers such as butyl rubber, polyisoprene, polyurethanes, ethylene-propylene copolymers, etc.

### Other Embodiments

Other embodiments of the invention will be apparent to those skilled in the art from a consideration of the specification or practice of the invention disclosed herein.

25 For example, turf according to the invention that changes color in response to a relatively small change in environment could also be used on golfing targets (*e.g.*, on artificial greens) to determine ball landing position and roll (*e.g.*, for putting and chipping).

Relatively sensitive fibers would be needed because of the low amount of stress and heat that would probably be imparted by a landing and rolling golf ball. These fibers would also be more sensitive to the relatively light stroke of a putter, which typically has a much slower velocity at impact than a full or partial swing with an iron or wood. It will be  
5 appreciated that a golf ball could be pre-heated or pre-dipped in a particular solvent or solution so that a thermochromic or chemically chromic substance changes color as the golf ball rolls across an inventive turf.

Artificial turf that changes color in response to a change in environmental conditions can be used in other sports and industrial applications, as well. For example,  
10 artificial turf similar to that of the golf mat of the invention could be used for a tennis court, which would allow line judges to easily determine whether a shot was inside or outside of the line. The inventive fibers could either be placed only in the region of the lines, or could cover the entire court (also providing some indication of players' movements, which could enhance spectator enjoyment).

15 In yet another application, the invention could be used in football which already uses artificial turf. By placing color-changing fibers near the lines, referees would, for example, have another tool to determine whether a receiver's feet were inside the line during a catch. Field goal kickers could use turf according to the invention as a training device. By placing the ball on the turf before kicking, the kicker can determine the path  
20 of his kick in the same way that a golfer can see how a divot would have been taken. Alternatively, the invention could be used in cricket to mark the point at which a bowled ball bounced. The invention could also be used in track and field, e.g., in high jumping, triple jumping, or long jumping, the turf could be used to mark the point of impact of a hop, skip, or jump.

25 In yet another embodiment of the invention, a color changing material is provided that includes a substrate and a film disposed on a surface of the substrate. The film includes a chromogen as described above. As described for fibers above, the chromogen

may be coated on the surface of the film or may be embedded within the film. In certain other embodiments, the film may consist of the chromogen. The film could, for example, be formed over a smooth substrate surface. An inventive film could be used on the lanes of a bowling alley, so that a bowler could clearly see the path of his ball. The film embodiment could also be used on dance floors, basketball courts, squash courts, or for marking safety areas in an industrial setting.

It is intended that the specification and examples be considered as exemplary only, with the true scope and spirit of the invention being indicated by the following claims.